

DP 1 loop graphs

Action Functional:

$$\begin{aligned}
 S_R = & \psi^\dagger (-Z_1 \partial_t - Z_4 (\mathbf{v} \cdot \nabla) - a Z_5 (\nabla \cdot \mathbf{v}) + Z_2 D \nabla^2 - Z_3 D \tau) \psi + \\
 & + \frac{D\lambda}{2} [Z_6 (\psi^\dagger)^2 \psi - Z_7 \psi^\dagger \psi^2] + Z_8 \frac{u_2}{2D} \psi^\dagger \psi \mathbf{v}^2 - \frac{1}{2} \mathbf{v} D_v^{-1} \mathbf{v}.
 \end{aligned} \tag{1}$$

Green function in the model

$$\begin{aligned}
 \langle \psi^\dagger \psi \rangle_{1-ir} = & i\omega Z_1 - D p^2 Z_2 - D \tau Z_3 + \text{[diagram: bubble with wavy line]} + \\
 & + \frac{1}{2} \text{[diagram: bubble with straight line]} + \frac{1}{2} \text{[diagram: bubble with wavy line]}
 \end{aligned} \tag{2}$$

$$\begin{aligned}
 \langle \psi^\dagger \psi \mathbf{v} \rangle_{1-ir} = & -ip_j Z_4 - iaq_j Z_5 + \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \\
 & + \text{[diagram: bubble with wavy line]} + \text{[diagram: bubble with wavy line]}
 \end{aligned} \tag{3}$$

$$\begin{aligned}
 \langle \psi^\dagger \psi^\dagger \psi \rangle_{1-ir} = & D\lambda Z_6 + 2 \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \\
 & + 2 \text{[diagram: triangle with wavy line]}
 \end{aligned} \tag{4}$$

$$\begin{aligned}
 \langle \psi^\dagger \psi \psi \rangle_{1-ir} = & -D\lambda Z_7 + 2 \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \\
 & + 2 \text{[diagram: triangle with wavy line]}
 \end{aligned} \tag{5}$$

$$\begin{aligned}
 \langle \psi^\dagger \psi \mathbf{v}^2 \rangle_{1-ir} = & \frac{u_2}{D} \delta_{ij} Z_8 + \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \\
 & + \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \\
 & + \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]} + \text{[diagram: triangle with wavy line]}
 \end{aligned}$$

p - momentum of the ψ and q - momentum of the \mathbf{v} in vertex $\psi^\dagger\psi\mathbf{v}$

- effective charge g_2

$$g_2 \equiv \lambda^2 \tag{6}$$

- Redefinition of charges g_1 and g_2

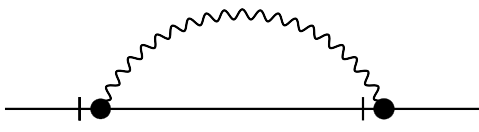
$$\frac{g_1}{16\pi^2} \rightarrow g_1 \qquad \frac{g_2}{16\pi^2} \rightarrow g_2$$

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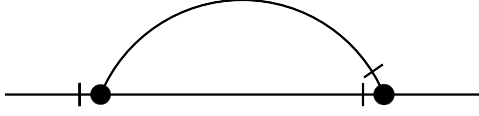
$$d = 4 - \epsilon$$

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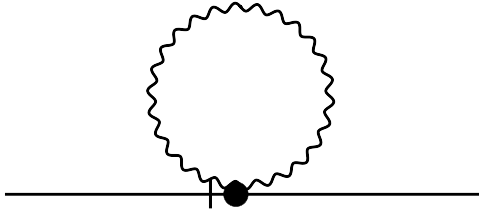
$$I_\epsilon = \frac{S_d}{(2\pi)^d} m^\epsilon \quad I_y = \frac{S_d}{(2\pi)^d} m^{-y} \tag{7}$$



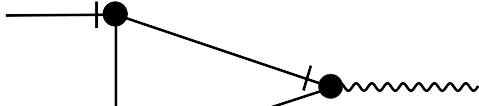
$$\begin{aligned}
& - \frac{g_1 D p^2 I_y}{2d(1+u_1)} \frac{1}{y} \left[d - 1 + \alpha - \frac{2\alpha}{1+u_1} + \frac{\alpha a(1-a)}{1+u_1} \left(\frac{4}{1+u_1} - d \right) \right] \\
& - i\omega \frac{g_1 \alpha a(1-a) I_y}{2(1+u_1)^2} \frac{1}{y} + \tau D \frac{g_1 \alpha a(1-a) I_y}{2(1+u_1)^2} \frac{1}{y}
\end{aligned}$$



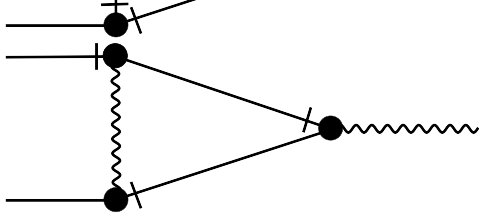
$$= \frac{I_\epsilon}{2D} \left[\frac{i\omega}{2D} - \tau - p^2 \frac{d-2}{2d} \right] \frac{1}{\epsilon}$$



$$= \frac{g_1 D^2 (d-1+\alpha)}{2} \frac{S_d}{(2\pi)^d} \int_0^{\sqrt{\tau}\Lambda} dk \quad k^{2-y-1}$$



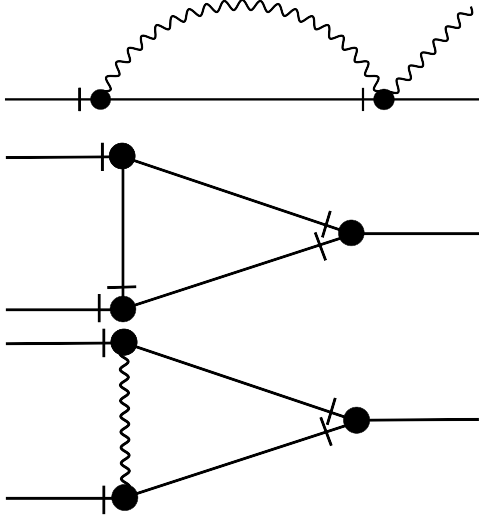
$$= \frac{-iI_\epsilon}{4dD^2} \frac{1}{\epsilon} [2p_j + q_j(ad + 3 - d)]$$



$$= \frac{ig_1\alpha I_y}{2(1+u_1)^2} \frac{1}{y} \left[(p_j + aq_j) \left(\frac{1}{d} + a - a^2 \right) - \frac{2a(1-a)}{(1+u_1)d} (2p_j + q_j) \right]$$



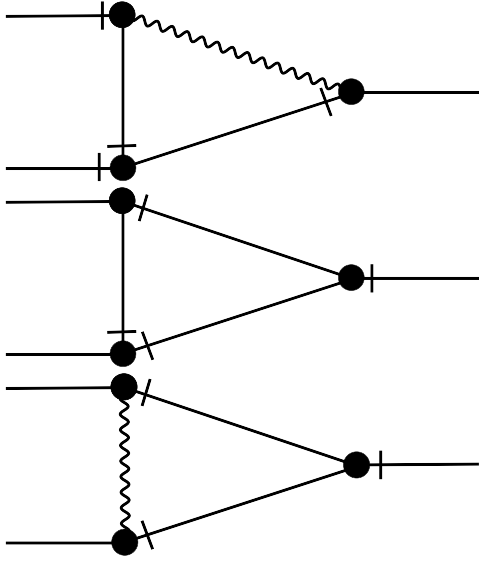
$$= -\frac{ip_j g_1 D I_y}{2d(1+u_1)} \frac{1}{y} \left[d - 1 + \alpha \left(1 - \frac{2a}{1+u_1} \right) \right]$$



$$= -\frac{i(p_j + q_j)g_1 D I_y}{2d(1 + u_1)} \frac{1}{y} \left[d - 1 + \alpha - \frac{2\alpha(1 - a)}{1 + u_1} \right]$$

$$= \frac{I_\epsilon}{4D^2} \frac{1}{\epsilon}$$

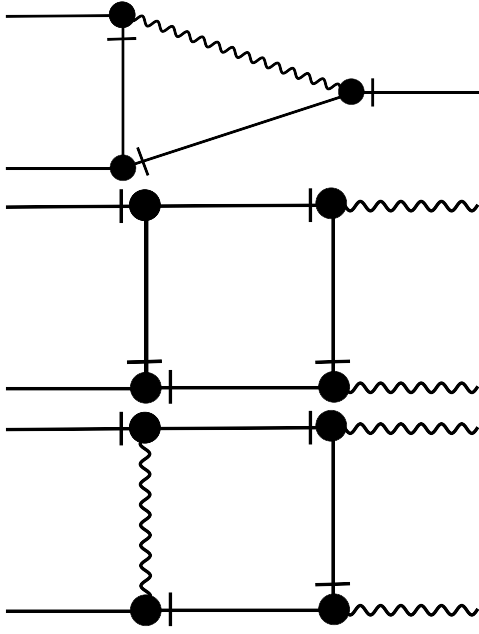
$$= \frac{\alpha g_1 I_y (1 - a)^2}{2(1 + u_1)} \frac{1}{y}$$



$$= -\frac{\alpha g_1 a(1-a)I_y}{2(1+u_1)^2} \frac{1}{y}$$

$$= \frac{I_\epsilon}{4D^2} \frac{1}{\epsilon}$$

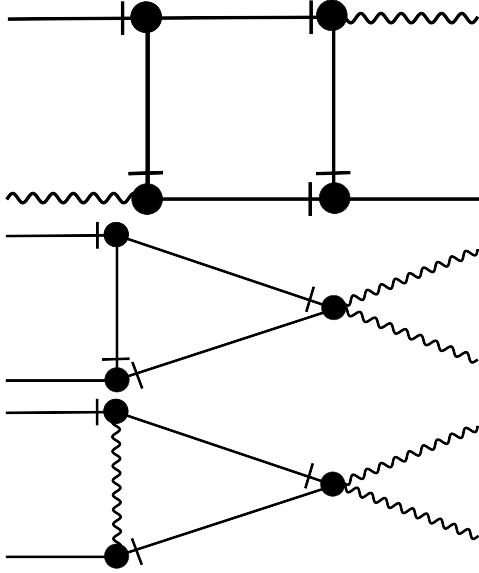
$$= \frac{g_1 \alpha a^2 I_y}{2(1+u_1)} \frac{1}{y}$$



$$= -\frac{g_1 \alpha a (1-a) I_y}{2(1+u_1)^2} \frac{1}{y}$$

$$= -\frac{I_\epsilon \delta_{ij}}{8dD^3} \frac{1}{\epsilon}$$

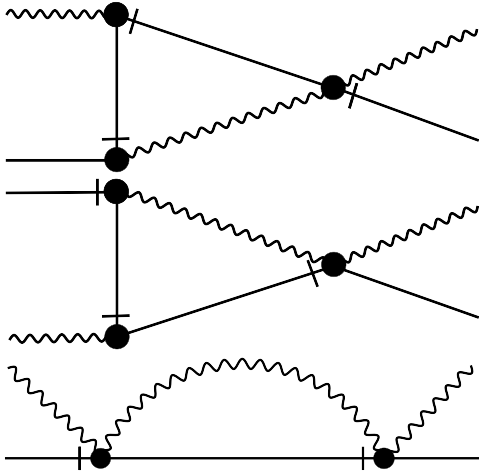
$$= \frac{g_1 \alpha a (1-a) I_y \delta_{ij}}{2d(1+u_1)^3 D} \frac{1}{y}$$



$$= \frac{I_\epsilon \delta_{ij}}{4dD^3} \frac{1}{\epsilon}$$

$$= \frac{I_\epsilon \delta_{ij}}{4D^2} \frac{1}{\epsilon}$$

$$= -\frac{\alpha g_1 a(1-a) I_y \delta_{ij}}{2(1+u_1)^2} \frac{1}{y}$$



$$= -\frac{g_1 \alpha a \delta_{ij} I_y}{2d(1+u_1)^2} \frac{1}{y}$$

$$= -\frac{\alpha g_1 I_y (1-a) \delta_{ij}}{2d(1+u_1)^2} \frac{1}{y}$$

$$= \frac{g_1 D \delta_{ij} I_y}{2d(1+u_1)} \frac{1}{y} (d-1+\alpha)$$

19.

$\psi^\dagger \psi \mathbf{v}^2$

21.

$\psi^\dagger \psi \mathbf{v}^2$

Propagators

$$\begin{array}{c} \text{---} \end{array} \begin{array}{c} | \\ \psi^+ \end{array} = \frac{1}{-i\omega + D(k^2 + \tau)}$$

$$\begin{array}{c} | \\ \text{---} \end{array} \begin{array}{c} \psi^+ \\ \psi \end{array} = \frac{1}{i\omega + D(k^2 + \tau)}$$

$$\begin{array}{c} \text{~~~~~} \\ 2^* V_i \end{array} \quad \begin{array}{c} V_j \end{array} = \frac{g_1 u_1 D^3 k^{4-d-y-\eta}}{\omega^2 + u_1^2 D^2 (k^2 - \eta)^2} (P_{ij}^k + \alpha Q_{ij}^k)$$

Vertices

$$\begin{array}{c} \text{---} \\ \psi^+ \end{array} \bullet \begin{array}{l} \text{---} \psi \\ \text{---} \psi \end{array} \quad 2^* = -D\lambda$$

$$\begin{array}{c} \text{---} \\ \psi \end{array} \bullet \begin{array}{l} \text{---} \psi^+ \\ \text{---} \psi^+ \end{array} \quad 2^* = D\lambda$$

$$\begin{array}{c} \text{---} \\ \psi^+ \end{array} \bullet \begin{array}{l} \text{~~~~~} V_j \\ \text{---} \psi \end{array} \quad 2^* = -ip_j - iaq_j$$

$$\begin{array}{c} \text{~~~~~} V_j \\ \text{~~~~~} V_i \end{array} \bullet \begin{array}{l} \text{---} \psi \\ \text{---} \psi^+ \end{array} \quad 2^* = \frac{u_2}{D} \delta_{ij}$$

1. $\psi^\dagger\psi$	Vertex factor: 1 Symmetry coefficient: 1
2. $\psi^\dagger\psi$	Vertex factor: $-D^2\lambda^2$ Symmetry coefficient: $\frac{1}{2}$
3. $\psi^\dagger\psi$	Vertex factor: $\frac{u_2}{D}\delta_{ij}$ Symmetry coefficient: $\frac{1}{2}$
4. $\psi^\dagger\psi\mathbf{v}$	Vertex factor: $-D^2\lambda^2$ Symmetry coefficient: 1
5. $\psi^\dagger\psi\mathbf{v}$	Vertex factor: 1 Symmetry coefficient: 1
6. $\psi^\dagger\psi\mathbf{v}$	Vertex factor: $\frac{u_2}{D}\delta_{ij}$ Symmetry coefficient: 1
7. $\psi^\dagger\psi\mathbf{v}$	Vertex factor: $\frac{u_2}{D}\delta_{ij}$ Symmetry coefficient: 1
8. $(\psi^\dagger)^2\psi$	Vertex factor: $-D^3\lambda^3$ Symmetry coefficient: 1
9. $(\psi^\dagger)^2\psi$	Vertex factor: $D\lambda$ Symmetry coefficient: 1
10. $(\psi^\dagger)^2\psi$	Vertex factor: $D\lambda$ Symmetry coefficient: 1
11. $\psi^\dagger\psi^2$	Vertex factor: $(D\lambda)^3$ Symmetry coefficient: 1

12. $\psi^\dagger\psi^2$	Vertex factor: $-D\lambda$
	Symmetry coefficient: 1

13. $\psi^\dagger\psi^2$	Vertex factor: $-D\lambda$
	Symmetry coefficient: 1

14. $\psi^\dagger\psi\mathbf{v}^2$	Vertex factor: $-D^2\lambda^2$
	Symmetry coefficient: 1

15. $\psi^\dagger\psi\mathbf{v}^2$	Vertex factor: 1
	Symmetry coefficient: 1

16. $\psi^\dagger\psi\mathbf{v}^2$	Vertex factor: $-D^2\lambda^2$
	Symmetry coefficient: 1

17. $\psi^\dagger\psi\mathbf{v}^2$	Vertex factor: $-Du_2\lambda^2\delta_{ij}$
	Symmetry coefficient: 1